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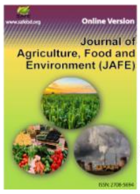

Research Article

Evaluation of Sylhet sadar upazila's geological formation for groundwater availability

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A B S T R A C T

There is sparse of hydrogeological data and insufficient knowledge in many areas of the country reliant on groundwater. Given the exponential expansion in groundwater consumption in recent years, it is imperative to comprehend how groundwater reservoirs respond to both natural and anthropogenic situations. Because of its extensive and unequal distribution, groundwater must be carefully studied in some locations to preserve this precious resource. This study was carried out to evaluate and assess the geological formation and some relevant parameters to enrich the geotechnical information of the study area for future use of groundwater. The soil samples used for the study were obtained from 8 SPT boreholes at 0 to 800 ft. depth at various work stations by percussion drilling method and all laboratory tests were conducted by BS 1377. Drilled soil sample with water was collected in a Polythene bag with a permanent marker pen at 20 ft. intervals of the drilling layer to perform a sieve analysis test. Percentage fines decreased with an increase in boring depth and curves were closely packed homogeneity. The quantity of free silt and clay progressively reduced and coarsen materials were formed with the increase in boring depth. Results show that soil particle sizes increase with boring depth up to the upper surface of it. However, the area is suitable in terms of groundwater availability.

Introduction

In terms of life and geologic processes, water comes second in importance to oxygen. If water is not used more effectively and appropriate investments are not made in its provision and protection, many people around the world will have to deal with a future without enough water. It is the basic building block of litho stratigraphy, which examines strata or rock layers. A formation needs to be big enough to be mapped on the surface or tracked underground. Geologic formations are frequently called for an enduring man-made or natural feature of the place where they were first observed. It is necessary to link subsoil exploration data and geological information. The tectonic setting and geology of Bangladesh are also important to assessing the Earthquake Hazards of this region. The majority of Bangladesh is located in the Ganga-Brahmaputra delta, which is the world's largest delta in terms of the amount of silt that is carried out to sea (Orton and Reading, 1993). There are three portions that make up the Jaintia Group, an ascending sequence of rocks that originated under marine conditions during the Palaeocene and Eocene periods from Bangladesh's Stable Platform. From lowest to highest, the Tura Formation, Sylhet Limestone Formation, and Kopili Shale are grouped (Khan, 1991; Reimann, 1993). In the Tura formation, white sandstone predominates, with a few thin coal layers intermittently present near the top. The subsurface unit in Bangladesh's northwest that has had the most development is the Sylhet Limestone Formation. The Surma group is separated into two formations: the upper, more argillaceous (clayey) Bokabil formation and the lower, sandier Bhuban formation. The sand-to-shale ratio within the Bokabil and Bhuban strata both exhibit significant lateral shifts and vertical fluctuations. The world's primary source of freshwater consumption is thought to be groundwater.

According to Ahmadian and Chavoshian (2012), 33% of the world's population depends on groundwater for every day, industrial, and agricultural needs. Groundwater extraction is significantly expanding along with the daily growth in the world population. According to Shamsudduha *et al.*, (2009), the main reason for many places' rising groundwater tables is groundwater extraction. Globally, the GW reserve is crucial for both industrial and domestic water supplies as well as irrigation operations (Adhikary *et al.*, 2011; Hoque *et al.*, 2007).

However, this unique natural resource is being taken at an alarming pace all around the world, just like many other rare natural resources. It is now evident that the continued viability of the existing groundwater supply system and the increased usage of surface water depend on a reliable assessment of the GW resources found in any site or watershed under consideration. This particular objective can be met by an integrated distributed hydrogeological model, which offers a number of advantages. However, given the previously defined hydrogeological boundary, this numerical model is a helpful tool for evaluating the recharge process, flow characteristics, and potential head distributions of the GW system (Kumar, 2012; Sinha, 2005). This can help assess the available GW resources, which can then help calculate the possible future impacts on the GW system under different options for water distribution (Wahid *et al.*, 2007; Sinha, 2005; Anderson and Woessner, 1992).

Aquifers are now well recognized as naturally occurring underground reservoirs that are extremely practical sources of fresh water and typically have enormous storage capacities. They are used in the manufacture of drinking water and for human use. The hydraulic properties of the amount and shape of void spaces affect how groundwater moves within soils and rocks. The three main kinds of groundwater geological formations that, in general, control the accessibility of groundwater resources are known as aquifers, aquitards, and aquicludes. From recharging zones to drainage zones, groundwater passes through flow routes that have various lengths, mostly interacting with surface water (SW) at low altitudes (Conant *et al.*, 2019). Over 70% of the whole irrigated land is fed by GW sources, and 97% of the population formerly relied on them for drinking (Hasan *et al.*, 2007). The vast alluvial aquifers of Bangladesh have shallow depths of GW, which supply the majority of the country's needs for drinking and agricultural water. The utilization of the GW resources for irrigation and other uses is essential to the government's agricultural ambition of increasing food independence in the country (Wahid *et al.*, 2007). The latest study revealed a rising or falling trend in the depth of the water table, which suggests that Bangladesh's groundwater is in an unacceptable condition. Sarkar and Ali (2009) researched the movements of the water table in Dhaka City and found a sharp upward change in the water table. Ali *et al.* (2011) employed a similar method to investigate the groundwater resources' long-term viability. In the North-Eastern region of Bangladesh, the study's findings were similar: a decline in the depth of the water table or a decline in the level of the groundwater. In North-Western Bangladesh, a parametric regression approach was used to show a decrease in groundwater level in the Barind area (Jahan *et al.*, 2010). Groundwater is under a great deal of pressure because it is used by the majority of humans. To illustrate the trend and geographical analysis potential for groundwater level fluctuation, the geological formation beneath the research region has been examined. There isn't a lot of readily available or accessible information about the aquifer systems in the research area. Sylhet Sadar Upazila is taken as a field of study. To determine the geotechnical parameters of the subsoil material in Sylhet Sadar Upazila, Sylhet district of Bangladesh, this study describes field activities and provides the findings including in-field and lab tests that were executed.

Objectives: the study's primary goal was to look into the geological formation and assess its usability. The specific objectives were: I. to investigate the geological formation of the area. II. To evaluate the accessibility of groundwater in the area.

Materials and Methods

2.1 Study area

Sylhet Sadar Upazila, the most populated Upazila of Sylhet district, with an area of 517.43 km^2 was the study area. The investigated area was the northeastern part of Sylhet district. A geographical map was shown in Figure 1.

2.2 Topographic and climatic characteristics of the study area

In Bangladesh's northeastern Sylhet Division, Sylhet Sadar Upazila, Sylhet is situated at 24.8917°N 91.8833°E. At higher elevations, Sylhet experiences a tropical monsoon climate typical of Bangladesh that verges on a humid subtropical climate. While the short dry season begins in November and lasts until February, the rainy season begins in April and is extremely hot and humid with frequent, intense showers and thunderstorms. Between May and September, almost 80% of the annual average rainfall, or 4,200 millimeters, falls. Under this research, 8 sites were selected for collecting field data as seen in the table.

Table 1. Different logging site of the study area.

Site	Location	Depth of Drilling(m)
A	Airport road	245
B	Khadimnagar	60
C	Baluchor	122
D	SAU campus	98
E	Shahporan	183
F	Tilagor	155
G	Majortila	153
H	Shibganj	67

Table 2. Standard size of Particles (ASTM).

Description	Diameter (mm)
Gravel	>2.0
Very coarse sand	1.0-2.0
Coarse sand	0.5-1.0
Medium sand	0.25-0.5
Fine sand	0.125-0.25
Very fine sand	0.0625-0.125
Silt	0.004-0.0625
Clay	<0.004

2.3 Drilling Method used in the study

In areas with good soil conditions, particularly for tiny constructions, all borings could be finished during the initial phase of the inquiry. The soil samples were collected from 8 boreholes ranging from 0 ft to 245 m of different depths by percussion drilling Method for Sampling of Soils (ASTM 1586). These 8 samples were named as samples A, B, C, D, E, F, G, and H. The type of proposed structure, its overall weight, the size, form, and placement of the loaded portions, the soil profile, and the physical characteristics of the soil that make up each stratum all play a role in determining the depth of exploration that was necessary. All soil samples were distributed all over the Sylhet Sadar. All borehole and sample data were recorded in a bore log. Clear and accurate data were recorded to describe the soil profile and sample locations. To identify the borehole log at a certain site location, numerical analysis was used.

In groundwater investigations for drilled well sites, these manual shallow drilling techniques may be utilized as inexpensive alternatives, particularly if geophysical surveys show to be inefficient, unavailable, or impractical due to ground conditions. When drilling was carried out under these circumstances exclusively for prospecting, only quick, tiny holes were dug. In Bangladesh, this technique had proven to be successful. Spacing and Number of Boring: Horizontal spacing between the boreholes to be decided as below: Buildings: 10 – 30 meters apart, Roads: 30 – 300 meters apart, Landslides: at least 5.0 boreholes in line for profile.

2.4 Soil Sample Collection

Drilled soil sample with water was collected in Polythene bags from 8 sites of Sylhet Sadar indicated by permanent Marker pen as 6 m intervals of drilling layer (such as 0-6 m, 6-12 m, 12-18 m, 18-24 m etc. Disturbed soil samples were collected at different depths to perform a Sieve-analysis test.

Types of the soil were determined by Hand feel test and sand layers were identified. Different layers of sand at 8 sites – Site A (198-245 m depth), Site B (36-54 m depth), Site C (90-122 m depth), Site D (76-90 m depth) , Site E (170-182 m depth), Site F (6-54 m depth), Site G (12-48 m depth) and Site H (36-60 m depth). In each of the borings, residual soils that were created by the parent rock's in-place weathering were found beneath the surficial soils. The remaining soils that were sampled were categorized as clays (CL/CH), silts (ML/MH), and sands (SM).

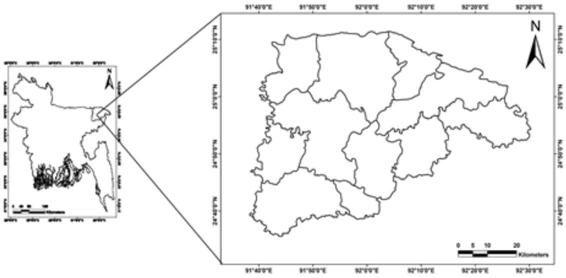

Figure 1. Geographical location of Sylhet Sadar Upazila

Figure 2. Soil sample collection

Table 3. Weight of the samples taken from different locations

Name of the site	Weight of soil sample (gm)
Site A	363.5
Site B	388
Site C	366
Site D	473
Site E	330
Site F	385
Site G	410
Site H	452

Table 4. Calculation of percentage finer (Sample A)

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage %	Percent Finer %
.600	.5	.13	.13	99.87
.425	12	3.3	3.43	96.57
.300	90	24.75	28.18	71.82
.150	198	54.75	82.65	17.35
.075	63	17.33	100	0

2.5 Drying soil samples and sieve analysis

By allowing a granular material to pass through a series of sieves with progressively smaller mesh sizes and weighing the amount of material that was stopped by each sieve as a percentage of the total mass, a sieve analysis (or gradation test) is a practice or procedure that is frequently used in civil engineering to assess the particle size distribution, also known as gradation, of the material. Depending on the precise technique, any type of non-organic or organic granular material, down to a minimum size, can be subjected to a sieve examination, including sands, crushed rock, clays, granite, feldspar, coal, and soil, a wide range of produced powders, grain, and seeds. It is perhaps the most popular method of particle size since it is so straightforward.

In civil engineering, a sieve analysis, also called a gradation test, is a practice or procedure that is commonly used to evaluate the particle size distribution, or gradation, of a material by allowing it to pass through a series of sieves with progressively smaller mesh sizes and weighing the amount of material that is stopped by each sieve as a percentage of the total mass. Any kind of non-organic or organic granular material, down to a minimum size, can be examined using a sieve, depending on the exact technique used. This includes soil, a variety of manufactured powders, grains, and seeds, as well as sands, crushed rock, clays, granite, feldspar, and coal. After collecting sand from different layers, the soil sample was dried at 105 to 110 ˚C in a thermostatically controlled hot air oven. Then this drying sample was allowed to cool and the weight of each sample was measured. The size of the sieve was taken separately for the analysis as 0.600 mm, 0.425 mm, 0.300 mm, 0.150 mm, and 0.075 mm. For analyzing the soil, the stack of sieves was arranged.

The soil sample was poured into the top sieve, and the stack of sieve was placed in a mechanical shaker. After shaking for about 10 min, the stack of sieve was removed from the shaker and transferred contents to a piece of paper. Then weight of every level of mould was measured and recorded. The weight of the empty mold was also measured.

Results and Discussion

The Particle-size distribution curves are typically used to display the findings of sieve analysis. The percent finer is presented in the arithmetic scale, and the particle sizes are exemplified in the log scale. The sieve analysis results, and the hydrometer analysis results for the finer fraction, together make up the particle-size distribution curve for sample A.

This is because soil particles typically have uneven shapes. The intermediate dimension of a particle can be determined using sieve analysis. The proportion of the total weight of soil that passes through each sieve determines the way sieve analysis results are often expressed.

Figure 3, sample A shows that the percentage of finer particles increased at a higher rate up to a size of 0.4 mm. Then the rate decreased with the increase of particle size. This demonstrates that this particular soil graph indicates a soil that almost entirely comprises particles of various sizes. Because of this, it is claimed that this curve represents well-graded soil. The soil sample B's particle size distribution is depicted in Figure 3, sample B also shows almost same result of the sample A where percentage of finer particles increased at higher rate up to 0.4 mm. Then the rate decrease with the increase of particle size.

Table 5. Calculation of percentage finer (Sample B).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.6	.15	.15	99.85
.425	10	2.5	2.65	97.35
.300	77	19.8	22.45	77.55
.150	232	60	82.45	17.55
.075	68	17.5	99.95	.05

Table 6. Calculation of percentage finer (Sample C).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.4	.11	.11	99.89
.425	3.3	.9	1.01	98.99
.300	135.3	36.96	37.97	62.03
.150	181.2	49.5	87.47	12.53
.075	44.66	12.2	100	0

Table 7. Calculation of percentage finer (Sample D).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.7	.18	.18	99.82
.425	9.8	2.62	2.8	97.2
.300	90	24.12	26.92	73.08
.150	202	54.15	81.07	18.93
.075	70	18.76	99.83	.17

Table 8. Calculation of percentage finer (Sample E).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.75	.22	.22	99.78
.425	10	3.03	3.25	96.75
.300	115	34.84	38.09	61.91
.150	153	46.36	84.45	15.55
.075	51	15.45	100	0

Table 9. Calculation of percentage finer (Sample F).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.56	.14	.14	99.86
.425	13	3.37	3.51	96.49
.300	105	27.27	30.78	69.22
.150	219	56.88	87.66	12.34
.075	47	12.2	100	0

Table 10. Calculation of percentage finer (Sample G).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer %
.600	.5	.12	.12	99.98
.425	12.5	3	3.12	96.88
.300	120	29.26	32.38	67.12
.150	233	56.82	89.2	10.8
.075	44	10.73	99.93	.07

Table 11. Calculation of percentage finer (Sample H).

Sieve no	Mass retained in each sieve (gm)	Percent Retained in each sieve (%)	Cumulative percentage	Percent Finer%
.600	.5	.11	.11	99.89
.425	17	3.76	3.87	96.13
.300	140	30.97	34.84	65.16
.150	253	55.97	90.81	9.19
.075	41	9	99.81	.19

Figure 4, sample C shows that percentage of finer particles increased at higher rate up to 0.4 mm and decreased up to 0.6 mm at a higher rate than Sample A and Sample B.

Figure 4, sample D shows that the percentage of finer particles which increased at a higher rate up to 0.4 mm, then did not increase and remained the same.

Figure 5, sample E shows almost the same result in which the percentage of finer particles increased at a higher rate up to 0.4 mm, then remained the same and sample F also shows that the percentage of finer particles increased at a higher rate up to 0.4 mm. Then the rate decreases with the increase in particle size which is almost the same.

Figure 6, shows that percentage of finer particles increased at higher rate up to 0.4 mm particle size, then decrease which is almost same result.

The results of the particle size distribution pattern of diverse samples from different sites are substantially identical, as shown in Figure 7. The percentage of finer particles increased at a higher rate up to 0.425 mm particle size. Then the rate decreases up to 0.6 mm. This soil graph depicts a soil that almost entirely consists of particles of various sizes. It is claimed that this curve represents well-graded soil. These soils contain all the different-sized particles. The percentage of fines often dropped as the drilling depth increased, and the curves were tightly packed, showing homogeneity. This might be because of overburden, which has compressed the soil below over time, resulting in larger particles with stronger connections.

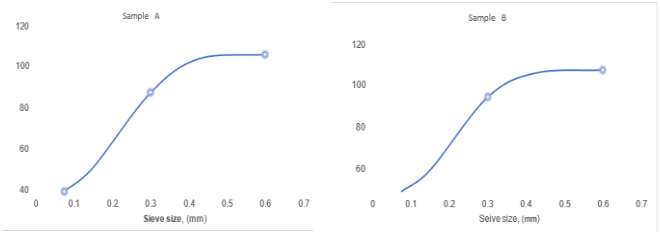

Figure 3. Particle size distribution pattern (Sample A & B).

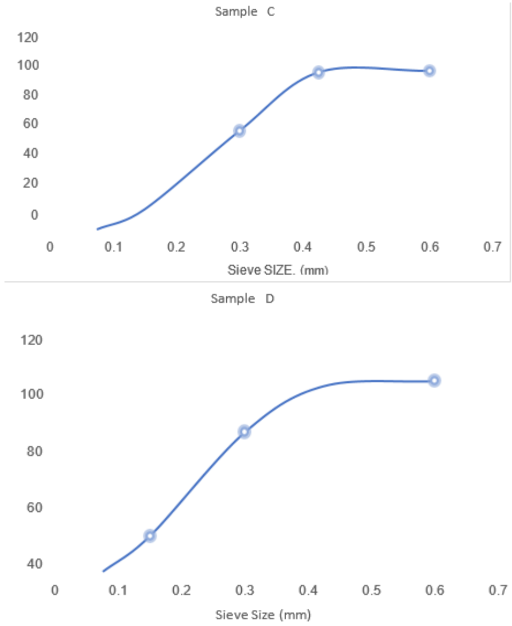

Figure 4. Particle size distribution pattern (Sample C &D).

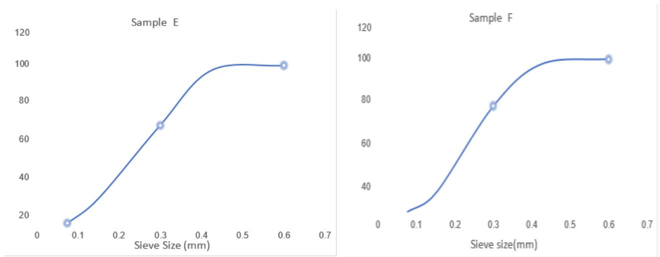

Figure 5. Particle size distribution pattern (Sample E & F).

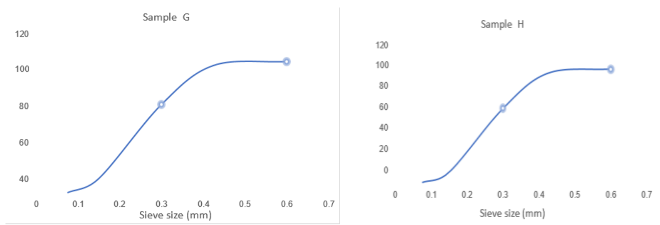

Figure 6. Particle size distribution pattern (Sample G & H).

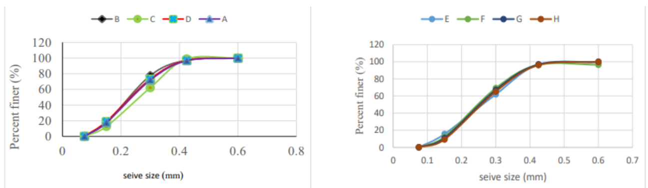

Figure 7. Particle size distribution pattern of various samples (A, B, C, D, E, F, G, and H sites).

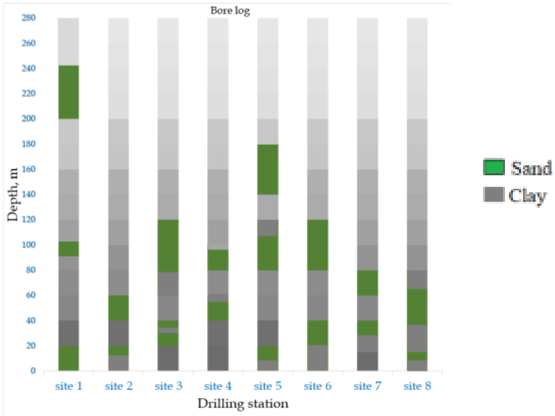

Figure 8. Bore log of drilling stations at Sylhet Sadar Upazila.

3.1 Bore Log

The layers of different depths of the eight borehole stations are given below. Each layer interval is taken as 6 m. Some boreholes are not able to go below 60 m because of adverse weather conditions at workstations. The anticipated borehole log may be helpful for the early stages of project site selection, land use planning, zoning laws, pre-disaster planning, and capital investment planning in this region. Data from eight boreholes were analyzed to explain the soil condition of different locations in this Upazila. Bore log relative depth representation from ground level.

Figure 8, shows that a bunch of handsome water layer (sand layer) is found in site A which is 6-18 m, 90-102 m, and 198-240 m. The water layer found in site B is 12-18 m and 36-60 m. Site C shows good geological formation for groundwater accumulation. The water layer found in site C is 18-30 m, 36-42 m, and 98-120 m. The water layer found in site D is 42-54 m and 78-96 m. In site E, the water layer found for groundwater accumulation is 12-24 m, 80-110 m, and 140-180 m. The water layer found in site F is 18-42 m and 78-120 m. The suitable water layer found in site G is 30-42 m and 60-78 m. A suitable water layer is found in site H which is 12-18 m and 42-66 m.

Finding of the study is that one major portion of the investigating site has low geological formation to contain groundwater. This is the site that covers the area of Airport Road. The first one-third and the tail portion of the area have sufficiently good formation for groundwater accumulation. The study shows that good aquifer layers may be found at the Khadimpara and Shibganj area about 60 to 80 m below the surface. This figure increases to about 210 to 240 m below or more on the Airport road area. SAU campus may fulfill its water requirement by setting up a deep tube well and supplying it to the whole University as a single body without wasting time and resources for individual tube wells for each structure because most of the shallow levels of the aquifer contain high amounts of Iron. A suitable layer for this site is 78 to 96 m. At site B (Khadimpara) area, a suitable aquifer layer was found in 36 to 60 m. A suitable aquifer layer for site C (Baluchor area) is about 98 to 120 m. At site E (Shahporan area), a 140 to 180 m layer is suitable for groundwater accumulation. Aquifer layer for site F is 78 to 120 m. The suitable aquifer layer found in site G is 60-78 m and in site H is 42-66 m for healthy groundwater accumulation. So it will be a wise decision to drill these areas for any further establishment of tube wells in those range of layers. The particle size distribution curves of the aquifer materials showed very satisfactory results based on lab tests. Most of the layers meet the requirements. The shallow-level layers mainly contain huge amounts of clay.

All of the curves show almost similar results. The percentage of finer particles increased with the increases in particle size of the soil up to 0.4 mm. It then decreased with the increase in particle size. These soils contain all the different-sized particles. For this reason, these soils should be referred to as well-graded soil. The amount of loose silt and clay gradually decreased as drilling depth increased, and coarser materials formed instead.

Conclusion

The study's objectives were to identify, explore, and evaluate the geological formation's utility. One of the main challenges to Bangladesh's sociopolitical and economic realities and the changing global environment is resource management and maximizing its utilization. Tube well construction is a costly method. Sometimes further installation of tube wells may require groundwater accumulation which increases the cost. The findings obtained from this study can help the future installation of tube wells. Results of particle size distribution curves of different soil samples collected from different sites of the study area shows that all the soil particles are present in the soil. The Bore log of eight sites presents different water layers for tube well installation. Finally, the current analysis demonstrates unequivocally that this study will allow for any kind of preliminary evaluation of the groundwater resources in this study area, where the shortest data and information are accessible. The study area's geologic formation differs depending on one location to another.

The following recommendation may be considered for further research that is more field data rather than secondary data may be used for better assessment of groundwater. Identify the suitable water according to quality with water availability. More pumping tests can be conducted to determine the type of aquifer and its characteristics. Regular GWT and quality monitoring can be done. To reduce project operation and maintenance costs and to maximize resource usage, production well monitoring can also be done regularly.

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Conflict of Interests

The authors declare that there is no conflict of interest related to this article.

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